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EVALUATION OF STRAIN ENERGY RELEASE RATE OF EPOXY GLASS FIBRE LAMINATE (MODE - I)

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ABSTRACT

The conventional materials fail to meet the requirements of high technology applications like space applications. In order to meet the requirements like high temperature and wear resistances new materials are being searched. The composite materials are the best alternative for those applications.

The applications of composite materials have recently increased because of high strength/stiffness for lower weight, superior fatigue characteristics, facility to change fiber orientations, etc. At the same time, these materials pose new problems such as inter ply cracking, inter laminar de-lamination and fiber cracking. Composite materials failure can be reduced by increasing fracture toughness.

Aim is to evaluate the strain energy release rate of glass fiber/epoxy composites. Composites were prepared with glass fiber reinforced with epoxy based polymer. The strain energy release rate of the specimen was employed to conduct mode-I fracture test using special loading fixtures as per ASTM (d5528) standards.

KEYWORDS: Adhesives, Composites, Strain energy release rate, Delaminating, Cantilever Beam.

1. INTRODUCTION

The role of engineering materials in the development of modern technology need not be emphasized. It is materials through which a designer puts forward his ideas into practice. We use a variety of materials for our needs and comfort and have been developing new materials for meeting our technological requirements. As the levels of technology have become more and more sophisticated, the materials used also have to be correspondingly made more efficient and effective. Several performance characteristics are expected from these materials. The materials to be used for sophisticated applications like aircraft and space applications should have higher performance, efficiency and reliability.

The conventional material may not always be capable of meeting the demand of such environments. Hence new materials being created for meeting these performance requirements and composite materials from one class of such materials are developed.

Susceptibility to delamination is one of the major weaknesses of many advanced laminated composite structures. Knowledge of a laminated composite materials resistance to inter laminar fracture is useful for product development and material selection, further more a measure of the mode 1 inter laminar fracture toughness, independent of specimen geometry or method of loading introduction for useful for establishing design allowable used in damage tolerance analysis of composite structures made from these materials.

A recent survey on emerging technologies has given the composite materials one of the top ten fields in engineering. The increasing use of composite materials in structural and space applications generated considerable interest for the development of techniques to predict the response under various loading conditions.

The technology has progressed to a stage where never composite materials are being considered, on an experimental basis for numerous applications in various fields. Such as aircraft, satellite launching vehicles, racket missiles, railways, automobile, energy, construction, infrastructure, medical, biomedical, Marine, sports etc…

The composite Laminates are constructed by stacking several unidirectional layers in specified sequence of orientation. Hence, the failure of a single layer does not give the total failure of the laminate. However, it leads to progressive failure of the laminate. The common modes of failure in the composite materials are crack growth, fiber breakage and delaminating. Hence the study of crack growth behaviors in composite laminate is of special significance.

2. LITERATURE REVIEW

The researchers are working with the problems of inter ply cracking, de- lamination and fiber cracking. This work is aimed at predicting the extent of crack propagation in a FRP composite laminate subjected to loads.

Chamis., presented the difference between fiber composites and traditional materials. any predictive approach for simulating structural fracture in fiber composites needs To formally quantify :(1)all possible fracture modes ,(2) the types of flaws they initiate, and (3) the coalescing and propagation of these flaws to critical dimensions for imminent fracture.

Guo., has developed experimental method to find dynamic mode-1 de-lamination fracture toughness at high crack-propagation speeds. This method uses load, deflection and crack extension. He also proposed the strain-energy release rate calculation for correlating the crack-propagation.

R. Velmurugan, S. Solaimurugan., Influence of in-plane fibre orientation on mode I interlaminar fracture toughness of stitched glass/polyester composites.

M.S. Sham Prasad, C.S. Venkatesha, T. Jayaraju., Experimental Methods of Determining Fracture Toughness of Fiber Reinforced Polymer Composites under Various Loading Conditions.

V. Alfred Franklin and T. Christopher., Fracture Energy Estimation of DCB Specimens Made of Glass/Epoxy: An Experimental Study.

Owaisur Rahman Shah*, Mostapha Tarfaoui., Determination of mode I & II strain energy release rates in composite foam core sandwiches. An experimental study of the composite foam core interfacial fracture resistance.

Ramesh Kumar., has proposed the method to accurately evaluate SERR in unidirectional FRP compact-tension specimen.

3. EXPERIMENTAL METHODS

3.1 Preparation of Specimen

Materials:

1. Glass Fibre:

Fibre glass has a white color and is available as a dry fiber fabric as shown in Fig.1.

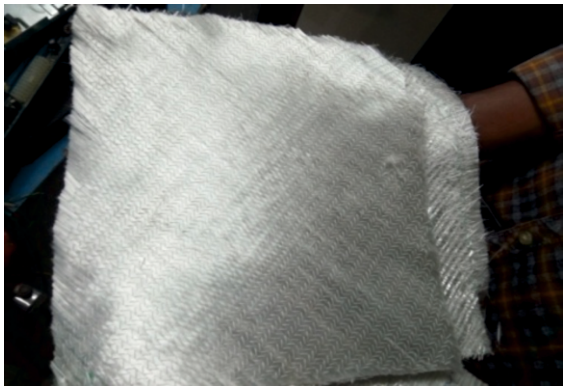

Figure 1: Glass Fibre

2. Epoxy Resin and Hardener:

Epoxy resins and hardener (as shown in Fig 2) are much more expensive than polyester resins because of the high cost of the precursor chemicals most notably

epichlorohydrin. However, the increased complexity of the 'epoxy' polymer chain and the potential for a greater degree of control of the cross linking process gives a much improved matrix in terms of strength and ductility. Most epoxies require the resin and hardener to be mixed in equal proportions and for full strength it requires heating to complete the curing process. This can be advantageous as the resin can be applied directly to the fibers and curing needs only at the time of manufacture which is known as pre-preg or pre impregnated fibre.

Epoxy polymers are made by reacting epichlorohydrin with biphenol-A in an alkaline solution which absorbs the HCl released during the condensation polymerization reaction. Each chain has a molecular weight between 900 and 3000 within the polymer chain. The epoxy is cured by adding a hardener in equal amounts and by heating it to about 120°C. The hardeners are usually short chain diamines such as ethylene diamine.

It is a substance or mixture which is added to plastic composition to promote or to control the curing action by taking part in it. It is also added to control the degree of hardness of the cured film. The required mixture of resin & hardener is made by mixing them in (10:1) parts in a beaker. When the epoxy resins are modified with different contents of particles which were prepared through vacuum assisted hand lay-up procedures, they get diffused into unidirectional fibers to form the glass fiber/epoxy composites. The process here is that the final mixture epoxy resin with the H-100 curing agent is poured on one dry glass fiber layer and then impregnated into the dry fibers with the assistance of a hand roller until the fiber bundles were permeated completely by the resin. Then, another ply of dry fiber was stacked on it. The process continues until the 12 layers of glass fibers are fabricated. Since the interlaminar fracture toughness of composites was measured from the double cantilever beam (DCB) specimens, during the process, a porous film was inserted in the mid-plane of the laminates for the creation of pre-crack. The entire stacking was then sandwiched between two steel plates with porous Teflon fabric on the surfaces and then sealed within a vacuum bag. The whole laminates were cured in a hot press with a suggested temperature profile under vacuum conditions. Fig 3 shows the prepared laminates.

Fig 2: Epoxy Resin and Hardener

Fig 3: Prepared samples

4.3 Test Procedure

Strain energy release rate was evaluated from the specimens that were made of ply laminates with a porous film inserted in the mid-plane during the layup process for creating the initial crack.. Symmetric loadings applied in opposite directions were transferred into the cracked end of the specimens through a pair of hinges bonded on the specimen surfaces resulting in the mode I crack extension. Prior to the fracture tests, specimens were pulled out such that the precrack can extend around 30 mm penetrating the resin enriched area and reach the "true" crack tip where the strain energy release rate begin to be measured. All specimen preparations and experimental procedures were performed based on ASTM standard d5528.

Fig 4: Mode-I Testing Machine

Fig 5: Mode-I Machine with Sample testing

5. Results

Mode 1 strain energy release rate test as per ASTM D5528 standard have been carried out on testing machine. The Results from the test have been evaluated as per ASTM D5528 and computed and recorded.

The strain energy release rate is calculated as follows:

$$G_I = \frac{12p^2a^2}{EB^2h^3}$$

Where, P: load, a: crack length, E:young's modulus, B: width of specimen, h: height of thickness of specimen.

$$G_I = \frac{12 \times 97.89^2 \times 49.72^2}{597.61 \times 25^2 \times 2.5^3}$$

=48.70 J/ m^2

The following are the results of experiment

Table 1, For specimen 'C' with orientation (0°,-45°,45°,0°):

Sr. no	Load, P (N)	Crack length, a (mm)	Young's modulus, E (Mpa)	Strain energy release rate, G_I (J/m^2)
1	97.89	49.72	597.61	48.70
2	76.43	42.16	718.44	17.75
3	68.94	81.33	185.57	208.16
4	140.75	91.73	224.78	911.26
Avg	96.00	66.23	431.60	296.467

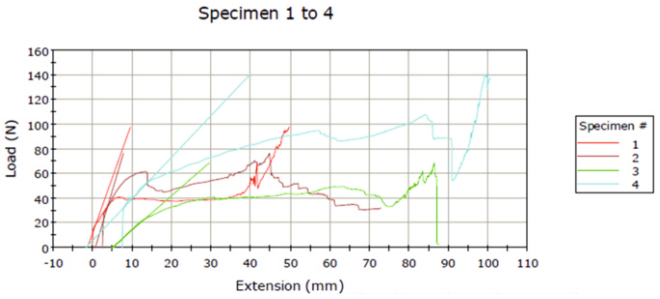

Table 2, for specimen 'D' with orientation (45°,-45°, 45°,-45°):

Sr. no	Load, P (N)	Crack length, a (mm)	Young's modulus, E (Mpa)	Strain energy release rate, G_I (J/m^2)
1	146.77	44.10	381.98	134.76
2	57.09	88.23	329.20	94.70
3	82.90	68.73	219.67	181.59
4	58.48	29.41	296.07	12.27
Avg	86.31	57.61	306.73	105.83

Table 3, For specimen 'E' with orientation (45°,90°,45°,90°):

Sr. no	Load, P (N)	Crack length, a (mm)	Young's modulus, E (Mpa)	Strain energy release rate, G_I (J/m^2)
1	54.94	20.48	532.61	2.92
2	67.60	18.42	594.41	3.20
3	68.07	17.96	650.52	2.82
4	35.71	43.36	122.67	24.01
Avg	56.58	25.06	475.05	8.23

Table 4, For specimen 'F' with orientation (0°,90°,0°,90°):

Sr. no	Load, P (N)	Crack length, a (mm)	Young's modulus, E (Mpa)	Strain energy release rate, G_I (J/m^2)
1	63.78	223.34	448.27	556.21
2	91.34	24.86	356.70	17.76
3	206.53	26.93	521.26	72.92
4	155.64	61.96	1200.64	95.17
Avg	129.32	84.27	631.72	185.515

Conclusion:

The strain energy release rate is more for 'C' which indicates that the crack growth is less for this sample that is for orientation (0°,-45°,45°,0°). This is because of the high fracture toughness.

That indicates that the above oriented specimen is preferable among all the other oriented specimens.

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